PAR 1110.2 Cost Effectiveness Calculations - Preliminary Draft (see notes)

Fuel	BIOGAS	BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS
RECLAIM?			RECLAIM	RECLAIM	RECLAIM	RECLAIM	RECLAIM	RECLAIM	RECLAIM
BACT?			BACT	BACT	NON-BACT	NON-BACT	NON-BACT	NON-BACT	NON-BACT
Rich-Burn or Lean-Burn?			RICH	RICH	RICH	RICH	LEAN-4S	LEAN-2S	LEAN
>1000 HP or NOx-Major?	=>1000	<1000	MAJOR	NON-MAJOR	MAJOR	NON-MAJOR	MAJOR	MAJOR	NON-MAJOR
Number of Engines (Survey Data)	41	13	1	16	1	36	13	15	8
Number of Engines (Total Population))	59	19	1	23	1	52	19	22	11
Average HP (Survey Data)	2,682	625	2,000	568	2,068	333	3,265	1,779	341
Total HP (Total Population)	158,238	11,875	2,000	13,064	2,068	17,316	62,035	39,138	3,751
New CEMS (Survey Data)		4.315		4.399		10.619			1.975
New CEMS (Total Population)		6.200		6.320		15.257			2.838
Non-CEMS Engines (Survey Data)		4		6		6			3
Non-CEMS Engines (Total Population)		6		9		9			4
Baseline NOx, ppmvd @ 15% O2	43.3	38.1	1	55	25	25	72	106	50
Baseline VOC, ppmvd @ 15% O2	43.1	48	1140	150	44	44	83	148	37
Baseline NOx, TPY	853.3	56.3	0.2	89.5	6.4	53.9	556.2	516.7	23.4
Baseline VOC, TPY	295.4	24.7	98.8	84.9	3.9	33.0	223.0	250.9	6.0
Controlled NOx, ppmvd @ 15% O2	11	11	11	11	11	11	72	1.8	
Controlled VOC, ppmvd @ 15% O2	30	30	30	30	30	30	30	1.5	30
Controlled NOx, TPY	216.8	16.3	2.7	17.9	2.8	23.7	556.2	8.7	0.0
Controlled VOC, TPY	205.6	15.4	2.6	17.0	2.7	22.5	80.6	2.5	4.9
(NOx+VOC) Reduction, 10-Yr Tons	7,263	493	937	1,395	49	407	1,424	7,564	245

Technology to Reduce Emissions to Natural Gas BACT	Gas Cleanup System, SCR and Oxidation Catalyst	Gas Cleanup System, SCR and Oxidation Catalyst			Upgrade Three-Way Catalyst to Meet BACT	Upgrade Three-Way Catalyst to Meet BACT	Install Oxidation Catalyst	Replace with Electric Motor	Install Oxidation Catalyst
Initial Cost, $	100,865,416	13,299,467	0	0	49,125	1,029,997	611,517	1,588,264	140,996
Annual O&M Cost, $	17,392,704	1,906,929	0	0	9,657	248,106	129,849	6,338,801	39,669
Add CO Analyzer									
Initial Cost, $	826,000	0	14,000	0	14,000	0	266,000	0	0
Annual O&M Cost, $	0	0	0	0	0	0	0	0	0
New CEMS									
Initial Cost, $	0	1,066,351	0	1,087,109	0	2,624,236	0	0	488,075
Annual O&M Cost, $	0	216,990	0	221,214	0	534,001	0	0	99,318
Add AFRC									
Initial Cost, $	0	120,000	0	180,000	0	180,000	0	0	80,000
Annual O&M Cost, $	0	18,000	0	27,000	0	27,000	0	0	12,000
Incr Source Testing and I&M Program									
Initial Cost, $	0	44,333	0	66,500	0	66,500	0	0	29,555
Annual O&M Cost, $	0	82,763	0	124,144	0	124,144	0	0	55,175
Total Initial Cost, $	101,691,416	14,530,150	14,000	1,333,609	63,125	3,900,733	877,517	1,588,264	738,626
Total Annual O&M Cost, $	17,392,704	2,224,682	0	372,358	9,657	933,251	129,849	6,338,801	206,162
Present Value of 10-Yr Costs, $	248,485,841	33,306,464	14,000	4,476,309	144,633	11,777,374	1,973,447	55,087,745	2,478,632
Cost Effectiveness, $ per ton (NOx+VOC)	**34,212**	**67,509**	**15**	**3,209**	**2,976**	**28,943**	**1,386**	**7,283**	**10,119**

Incremental Analysis	Upgrade to PUC Gas, Microturbines, Fuel Cells (to be added)	Upgrade to PUC Gas, Microturbines, Fuel Cells (to be added)	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor		Replace with Electric Motor
Power Plant Emissions, TPY									
NOx			0.4	2.9	0.5	3.8	13.6		0.8
VOC			0.1	0.8	0.1	1.1	3.9		0.2
(NOx+VOC) Reduction, 10-Yr Tons			984	1,707	98	820	7,617	7,676	283
Initial Cost, $			74,013	1,375,377	74,556	2,929,950	1,580,413		621,240
Annual O&M Cost, $			316,518	2,067,498	327,280	2,740,417	9,817,611		593,630
Present Value of Ten-Year Costs, $			2,745,429	18,825,064	2,836,800	26,059,067	84,441,047		5,631,480
Average* Cost Effectiveness, $/ton (NOx+VOC)			**2,789**	**11,030**	**28,960**	**31,772**	**11,085**		**19,893**
Incremental Cost Effectiveness, $/ton (NOx+VOC)			**57,221**	**46,019**	**54,544**	**34,557**	**13,316**		**82,663**

*Rule 1110.2 Baseline

PAR 1110.2 Cost Effectiveness Calculations - Preliminary Draft (see notes)

Fuel	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	NON-BIOGAS	
RECLAIM?	NON-RECLAIM	NON-RECLAIM	NON-RECLAIM	NON-RECLAIM	NON-RECLAIM	NON-RECLAIM	NON-RECLAIM	
BACT?	BACT	BACT	BACT	BACT	NON-BACT	NON-BACT	NON-BACT	
Rich-Burn or Lean-Burn?	RICH	RICH	LEAN	LEAN	RICH	RICH	LEAN	
>1000 HP or NOx-Major?	=>1000	<1000	=>1000	<1000	=>1000	<1000	<1000	Sums and Overall Averages
Number of Engines (Survey Data)	28	248	16	3	5	179	2	625
Number of Engines (Total Population))	40	356	23	4	7	257	3	897
Average HP (Survey Data)	1,674	354	2,144	886	1,172	284	183	
Total HP (Total Population)	66,960	126,024	49,312	3,544	8,204	72,988	549	637,066
New CEMS (Survey Data)		42.533		1		24.12		89
New CEMS (Total Population)		61.111		1.437		34.655		128
Non-CEMS Engines (Survey Data)		141		1		113	2	276
Non-CEMS Engines (Total Population)		203		1		162	3	394
Baseline NOx, ppmvd @ 15% O2	1	55	11	19.8	72	84	40	
Baseline VOC, ppmvd @ 15% O2	1140	150	300	10	175	175	25	
Baseline NOx, TPY	8.3	863.2	67.6	8.7	73.6	763.5	2.7	3,943.6
Baseline VOC, TPY	3,306.6	818.8	640.8	1.5	62.2	553.3	0.6	6,404.5
Controlled NOx, ppmvd @ 15% O2	11	11	11	11	11	11	11	
Controlled VOC, ppmvd @ 15% O2	30	30	30	30	30	30	30	
Controlled NOx, TPY	91.7	172.6	67.6	4.9	11.2	100.0	0.8	1,293.9
Controlled VOC, TPY	87.0	163.8	64.1	4.6	10.7	94.8	0.7	779.5
(NOx+VOC) Reduction, 10-Yr Tons	31,362	13,456	5,767	8	1,139	11,220	19	82,747
Technology to Reduce Emissions to Natural Gas BACT					Upgrade Three-Way Catalyst to Meet BACT	Upgrade Three-Way Catalyst to Meet BACT	Install SCR and Oxidation Catalyst	
Initial Cost, $	0	0	0	0	251,008	4,701,340	426,420	122,963,550
Annual O&M Cost, $	0	0	0	0	52,125	1,161,347	164,341	27,443,530
Add CO Analyzer								
Initial Cost, $	560,000	0	322,000	0	98,000	0	0	2,100,000
Annual O&M Cost, $	0	0	0	0	0	0	0	0
New CEMS								
Initial Cost, $	0	10,511,029	0	247,126	0	5,960,690	0	21,984,615
Annual O&M Cost, $	0	2,138,872	0	50,287	0	1,212,931	0	4,473,614
Add AFRC								
Initial Cost, $	0	4,060,000	0	20,000	0	3,240,000	60,000	7,940,000
Annual O&M Cost, $	0	609,000	0	3,000	0	486,000	9,000	1,191,000
Incr Source Testing and I&M Program								
Initial Cost, $	0	1,499,939	0	7,389	0	1,196,995	22,167	2,933,377
Annual O&M Cost, $	0	2,800,131	0	13,794	0	2,234,588	41,381	5,476,119
Total Initial Cost, $	560,000	16,070,967	322,000	274,515	349,008	15,099,025	508,587	157,921,542
Total Annual O&M Cost, $	0	5,548,003	0	67,081	52,125	5,094,865	214,723	38,584,262
Present Value of 10-Yr Costs, $	560,000	62,896,116	322,000	840,680	788,941	58,099,687	2,320,847	483,572,716
Cost Effectiveness, $ per ton (NOx+VOC)	**18**	**4,674**	**56**	**103,324**	**693**	**5,178**	**124,519**	**6,844**

Incremental Analysis	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	Replace with Electric Motor	
Power Plant Emissions, TPY								
NOx	14.7	27.7	10.8	0.8	1.8	16.0	0.1	94.1
VOC	4.2	7.9	3.1	0.2	0.5	4.6	0.0	26.9
(NOx+VOC) Reduction, 10-Yr Tons	32,960	16,464	6,944	93	1,334	12,962	32	89,975
Initial Cost, $	2,851,918	20,180,570	1,728,568	254,603	466,601	14,266,644	160,757	46,565,211
Annual O&M Cost, $	10,597,037	19,944,460	7,804,079	560,871	1,298,359	11,551,024	86,884	67,705,668
Present Value of Ten-Year Costs, $	92,290,913	188,511,811	67,594,992	4,988,352	11,424,748	111,757,285	894,060	618,001,047
Average* Cost Effectiveness, $/ton (NOx+VOC)	**2,800**	**11,460**	**9,734**	**53,799**	**8,562**	**8,622**	**28,167**	**6,869**
Incremental Cost Effectiveness, $/ton (NOx+VOC	**57,398**	**41,763**	**57,159**	**49,035**	**54,318**	**30,802**	**-108,889**	**18,600**

*Rule 1110.2 Baseline

PAR 1110.2 Cost Effectiveness Calculations - Preliminary Draft --Notes

General

Calculations assume 8000 hrs per year engine operation and 31% engine efficiency (HHV).
The ten-year present-value calculation assumes a 4% real interest rate.
Survey results were scaled up to represent total-population estimates based on 69.6% response rate to survey. Emission reductions and costs are for the total engine population.
Diesel engines (6 in the survey) are not included in the cost calculations. Survey data indicate that all diesels are in RECLAIM and operate with low VOC/CO and all have CEMS.
Number of new CEMS in a category may not be a whole number since CEMS may be shared (up to three on one CEMS) by engines at the same site but in different categories.

Baseline Emissions

Biogas Engines

Baseline emissions are horsepower-weighted averages of NOx limits, landfill gas VOC limits (40 ppm @ 15% O2 as methane) and average source test VOC results for digester gas engines (48 ppm @ 15% O2 as methane).

Rich-Burn Engines

BACT engines with CEMS--AQMD compliance tests show that CO (and presumably VOC) is 38 X BACT limit on average and that NOx is approximately 10% of the BACT limit on average.
BACT engines without CEMS--AQMD compliance tests show that both NOx and CO (and presumably VOC) are 5 X BACT limits.
Non-BACT engines without CEMS--AQMD compliance tests show that NOx is 2 X the Rule 1110.2 limit on average and CO (and presumably VOC) is 0.7 X the Rule 1110.2 limit on average. The Rule 1110.2 NOx limit used in the calculation was the horsepower-weighted average (36 ppm @ 15% O2 for = or >500 hp and 45 ppm @ 15% O2 for < limit as is found on Non-BACT engines without CEMS (0.7 X the Rule limit).
Non-BACT engines with CEMS--although there is no compliance test data for this category, it is assumed that CO and VOC are at least as high relative to the Rule 1110.2
Non-BACT engines in RECLAIM--baseline emissions are based on average source test results.

Lean-Burn Engines

BACT engines with CEMS--tests on a 737 hp, 4-stroke, lean-burn engine showed that minimum NOx was achieved with about 300 ppm VOC (corrected to 15% O2) (EPA-454/R-00-037: Testing of a 4-Stroke Lean Burn Gas-fired Reciprocating Internal Combustion Engine to Determine the Effectiveness of an Oxidation Reduction Catalyst System for Reduction of Hazardous Air Pollutant Emissions, September 2001.).
BACT engines without CEMS--AQMD compliance tests show that NOx was 1.8 X the BACT limit on average and CO (and presumably VOC) was 0.33 X the BACT limit on average.
Non-BACT engines in RECLAIM--baseline emissions are based on average source test results.
Non-BACT, non-RECLAIM engines--one compliance test showed 40 ppm NOx and 25 ppm VOC, both corercted to 15% O2.

Install fuel cleanup system, SCR system and oxidation catalyst on biogas-fired engine

	2682 hp		625 hp		Non-Biogas Engine 183 hp	
	Initial Costs, $	Annual Costs, $	Initial Costs, $	Annual Costs, $	Initial Costs, $	Annual Costs, $
Biogas cleanup (siloxane removal) system installed cost, $	1,073,247		447,871			
Sorbent disposal and replacement, $/yr		93,870		21,875		
Selective catalytic reduction system installed cost, $	260,799		94,654		46,550	
Startup	9,100		9,100		9,100	
Contingency (10%)	26,080		9,465		4,655	
Total	295,978		113,220		60,305	
Annual cleaning, replace catalyst every 3 years		45,466		17,776		9,758
Cost of urea, $/yr		32,553		22,855		22,855
Oxidation catalyst installed cost,$	29,279		10,562		6,431	
Annual cleaning, replace catalyst every 3 years		6,880		3,760		3,072
Power loss to blower for 9 in. H2O pressure drop @ $.083/kWh, $/yr		75,123		17,506		17,506
Project management- 160 hrs @ $55	8,800		8,800		8,800	
AQMD application fee	2,300		2,300		2,300	
Performance test	4,000		4,000		4,000	
Annual maintenance cost @ 3% of original equipment cost, $/yr		40,900		16,593		1,589
	1,709,583	294,792	699,972	100,365	142,140	54,780

Installed cost and annual cost for a biogas cleanup system was obtained from a vendor specializing in that equipment.
The SCR system costs were obtained from a vendor specializing in that equipment--see AQMD staff report "Proposed Amended Best Available Control Technology (BACT) Guidelines, Part D- Non-Major Polluting Facilities, Regarding Emergency Compression-ignition (Diesel) Engines", April 2003, Appendix H.
The oxidation catalyst installed cost was obtained from a vendor specializing in that equipment.

		2068 hp	333 hp	1172 hp	284 hp
Replace three-way catalyst to meet 11 ppm NOx					
New catalyst (installed) (vendor figure)		45,945	16,628	32,678	15,113
Project management (16 hrs @ $55)		880	880	880	880
AQMD application fee		2,300	2,300	2,300	2,300
Total		49,125	19,808	35,858	18,293
Annual O&M Cost	Annual maintenance, replace catalyst every 3 years	9,657	4,771	7,446	4,519

		3265 hp	341 hp
Install oxidation catalyst to meet 30 ppm VOC and 70 ppm CO			
Oxidation catalyst (Installed) (vendor figure)		29,005	9,638
Project management (16 hrs @ $55)		880	880
AQMD application fee		2,300	2,300
Total		32,185	12,818
Annual O&M Cost	Annual maintenance, replace catalyst every 3 years	6,834	3,606

	250 hp	750 hp	1779 hp
Replace engine with electric motor			
Engine removal (vendor figure)	15,000	15,000	15,000
Electric motor, installed (including electrical connections and controls) (vendor figure)	37,700	44,886	54,994
Project management (40 hrs @ $55)	2,200	2,200	2,200
Total	54,900	62,086	72,194
Cost of power (SCE TOU-8 rate schedule--$175/kW-Yr demand charges, $.088/kWh ann. avg.), $/Yr	173,487	520,461	1,234,532
Avoided cost of fuel @ $0.81 per therm, $/Yr	132,997	398,990	946,405
Net operating cost	40,490	121,470	288,127

Power and fuel calculations assume 31% engine efficiency, 95% motor efficiency (including line loss), 8000 hrs per year operation.
Emissions produced by central power plant assumed to be .07 NOx and .02 VOC (lb/MWh)
For biogas engine, additional emissions from flaring the gas are assumed to be .06 lb.MMBtu NOx and 40 ppm VOC (@ 15% O2).

Add CO analyzer to existing CEMS

The cost of a CO analyzer ($8,000 to $11,000) was obtained from a CEMS vendor. The cost of reprogramming the DAS is estimated to be about $3000. The impact on span gas costs is expected to be minimal since CO can be added to the NOx span gases at little additional cost. The impact on RATA tests is expected to be minimal.

Install New NOx-CO CEMS

The installed cost and annual cost of a NOx-CO CEMS were obtained from a vendor specializing in that equipment.

	Initial Costs, $	Annual Costs, $
NOx-CO CEMS	86,000	
Data Aquisition System	25,000	
Special Provisions for Sharing (AQMD estimate)	5,000	
Installation	20,000	
Certification Testing	4,200	
Startup and Training	25,000	
Project Management	2,800	
AQMD Fees	4,000	
Span Gases		10,000
RATAs (two per year)		10,000
Maintenance		15,000
	172,000	35,000

Install air/fuel ratio controller on a lean burn engine

The installed and operating cost of an air/fuel ratio controller was obtained from a vendor specializing in that equipment.

Installed Cost, $	20,000	
Operating Cost (periodic changeout of O2 sensor(s)), $/yr		3,000

Increased Source Testing and I&M Requirements for Non-CEMS Engines

	Initial Costs, $	Annual Costs, $
One additional source test every six years		0
AQMD Protocol and Report Evaluation Fees		186
Source test protocol with every source test		28
I&M Plan	880	
AQMD Plan Evaluation Fee	209	
Initial Parametric Test	1,300	
Alarm System (installed)	5,000	
Weekly/Monthly Emission Checks (18 tests per year)		5,400
Daily inspections		3,194
Repeat parametric test whenever O2 sensor is changed (quarterly)		5,200
	7,389	13,794